DOI azonosító: https://doi.org/10.53304/PS.2024.1-2.15

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Magical journey from hemp to cacti and mushrooms[1]

Introduction

In 2013, the Laboratory of Forensic Geology and Botany was established within the Department of Physics and Chemistry at the Hungarian Institute for Forensic Sciences (HIFS). In the year of its founding, six botanical expert appointment orders were received, and this number steadily increased in the following years, surpassing 300 orders per year from 2021 onwards. Approximately 90% of the botanical expert appointment orders submitted to the laboratory involve the identification of narcotic plants, hallucinogenic fungi, or their remnants and fragments. Among the known narcotic plants and hallucinogenic fungi, the following have been most frequently encountered in our laboratory in recent years: hemp (*Cannabis sativa L.*), peyote cactus (*Lophophora williamsii* (Lem. Ex Salm-Dyck) J. M. Coult), Peruvian torch cactus (*Cereus macrogonus* Salm-Dyck), Hawaiian baby woodrose (*Argyreia nervosa* (Burm. F.) Bojer), and psilocybe mushrooms (*Psilocybe spp*.), with hemp being the most commonly represented.

Hemp

The hemp plant belongs to the family Cannabinaceae. The two most well-known genera in this family are Cannabis and Humulus. The most famous and widespread species of the Humulus genus is common hop (*Humulus lupulus* L.), which differs significantly from hemp in terms of morphological characteristics. One of the most accepted classifications distinguishes

[1] This study is the English version of the presentation delivered at the conference 'The Science and Practice of Law Enforcement' held in Pécs 27.06.2024.

two subspecies of hemp (*Cannabis sativa* L.). One is Indian hemp (*Cannabis sativa ssp. indica*), and the other subspecies (Cannabis sativa ssp. sativa) has two known varieties: fibre and seed hemp (*Cannabis sativa ssp. sativa var. sativa*), which is cultivated under regulation, and wild hemp (*Cannabis sativa ssp. sativa var. spontanea*), a feral form that grows like a weed and can be found on forest edges, near fields, and on neglected land.[2] The term "wild hemp" is widely used, although many mistakenly refer to Indian hemp by this name, when in fact wild hemp is the weedy variety.
Different subspecies, varieties, and strains of hemp are crossbred for the cultivation of narcotic hemp varieties, resulting in thousands of hybrids today. Hemp contains delta-9-tetrahydrocannabinol (THC), a psychoactive substance.[3,] In recent years, an increasing number of hemp plants have been found to contain significant amounts of cannabidiol (CBD), a non-psychoactive substance.

Based on cannabinoid content, three chemotypes of hemp can be distinguished: THC-dominant, THC and CBD equivalent, and CBD-dominant. The difference between these chemotypes lies in the ratio of THC to CBD. THC-dominant plants contain a higher proportion of THC, while CBD-dominant plants have a higher CBD content. In the case of THC and CBD equivalent hemp plants, the THC and CBD levels are nearly identical. One of the goals of an ongoing joint research project between the HIFS's Drug Investigation Department and the laboratory is to determine whether it is possible to predict chemotype based on micro- and macromorphological characteristics.

[2] UNODC ID (2022): ST/NAR/40 Recommended Methods for the Identification and Analysis of Cannabis and Cannabis Products, Vienna, Chapter 3

[3] 1979. évi 25. törvényerejű rendelet a pszichotróp anyagokról szóló, Bécsben az 1971. évi február hó 21. napján aláírt egyezmény kihirdetéséről, I. jegyzék [Decree-Law No 25 of 1979 promulgating the Convention on Psychotropic Substances, signed at Vienna on 21 February 1971, Schedule I]
78/2022. (XII. 28.) BM rendelet az ellenőrzött anyagokról, 2. Pszichotróp anyagok 2. jegyzék [78/2022.(XII. 28.) BM Decree on Controlled Substances, Psychotropic Substances 2, Schedule 2]

During botanical examinations in the field or laboratory, the 4-aminophenol (4-AP) rapid test can be used to determine whether THC or CBD is predominant in the tested hemp plant. The test result is only indicative and does not replace analytical examinations that quantify the active ingredients. The 4-AP rapid test produces different colour reactions based on the ratio of active ingredients: for THC-dominant plants, the colourless solution turns blue, for CBD-dominant hemp it turns pink, and for THC and CBD equivalent plants, it turns purple.[4]

Legislation distinguishes two categories of hemp based on active ingredient content: high-THC and low-THC hemp. Low-THC hemps are fibre and seed hemp varieties of the species *Cannabis sativa* L., whose THC content, based on tests conducted during the state recognition process or for inclusion in the Community Variety List, does not exceed 0.2% in the air-dried, homogenized parts of the plant (excluding roots and stems). High-THC hemp varieties are those that do not qualify as low-THC.[5]

Legislation also differentiates between the following terms: cannabis plant, cannabis, cannabis resin, and marijuana. Cannabis plant refers to any plant belonging to the Cannabis genus. Cannabis refers to the flowering or fruiting tops of the cannabis plant, regardless of the name used (Figure 1). Cannabis resin is the resin extracted or separated from the cannabis plant. Marijuana refers to the parts of the cannabis plant that are free from the low-THC elements (seeds, stems, roots). Marijuana is also a widely used term in everyday language. The key difference between cannabis and marijuana is that cannabis may contain low-THC parts of the plant (e.g.,

[4] Lewis, K. – Wagner, R. - Rodriguez-Cruz, S. E. – Weaver, M. J. – Dumke, J. C. (2021): Validation of the 4-aminophenol colour test for the differentiation of marijuana-type and hemp-type cannabis, J Forensic Sci. 2021. 66:285-294

[5] 162/2003. (X. 16.) Korm. rendelet a kábítószer előállítására alkalmas növények termesztésének, forgalmazásának és felhasználásának rendjéről, [Government Decree 162/2003 (X. 16.) on the regulation of the cultivation, distribution and use of plants suitable for the production of narcotics] 1. § i)

stems), while marijuana is a processed product ready for "consumption." Both cannabis and cannabis resin are classified as narcotics on their own.[6]

Hemp is an annual, herbaceous, short-day plant. Short-day plants require at least 12 hours of darkness to initiate flowering. By adjusting the ratio of light to darkness, the flowering time can be modified according to the grower's needs. Seed-grown hemp plants develop a taproot system (Figure 2). In cases where propagation is done through cuttings, the resulting clones develop adventitious roots (Figure 3). The plant's shoot system is branching, and its stems are ribbed and twisting. During the vegetative phase, the leaves are arranged oppositely, and during the generative phase, they are alternate. Hemp has palmately compound leaves, with the "fingers" consisting of leaflets, the number of which depends on the cultivar and the plant's age. Typical leaflet counts are 3-5-7-9-11-13. The leaflets are lance-shaped, with serrated edges, and the veins are prominent on the underside. The plant's surface is covered with characteristic cystolith hairs and glandular hairs, which vary in distribution depending on the part of the plant.[7] The significance of glandular hairs lies in the production and accumulation of cannabinoids. Three types of glandular hairs can be distinguished, with the so-called long-stalked glandular hairs being the primary site of cannabinoid production.[8]

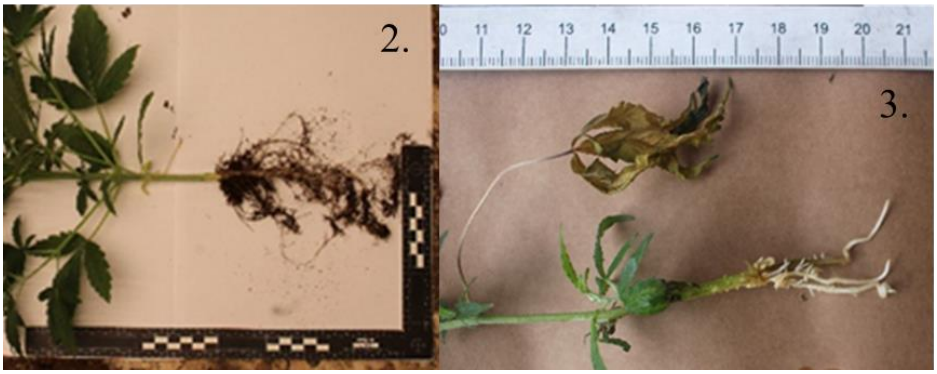
Based on morphological characteristics, the species can be identified, and the method of propagation and the plant's developmental stage can be determined. However, morphological traits cannot be used to determine the subspecies, variety, or THC content.

[6] 1965. évi 4. törvényerejű rendelet a New-Yorkban, 1961. március 30-án kelt Egységes Kábítószer Egyezmény kihirdetéséről, I. jegyzék, IV. jegyzék [Legislative Decree No. 4 of 1965 proclaiming the Single Convention on Narcotic Drugs, signed at New York on 30 March 1961, Schedule I, Schedule IV]

[7] Bócsa, I. (2004): A kender és termesztése [Hemp and its cultivation], Argoinform Kiadó és Nyomda Kft.

[8] UNODC ID: ST/NAR/40 (2022): Ibid. Chapter 5

Figure 1
Female cannabis flowering tops. Source: HIFS



Figures 2 and 3
Taproot (2) and adventitious roots of the cannabis plant (3). Source: HIFS

Hemp is typically a dioecious plant, although monoecious specimens also occur. In dioecious hemp, male and female flowers are found on separate plants. Male flowers are arranged in paniculate clusters, while female flowers form spike-like inflorescences. The colour of the female flower stigmas changes as they mature, ranging from white to deep purple. Male flowers bloom earlier than female ones, and hemp is wind-pollinated.[9] The

[9] Bócsa, I. (2004): Ibid. Chapters. 4.5, 5.3

plant's sex cannot be determined until the flowers develop. The resin-producing glandular hairs, which contain THC and CBD, are most abundant on the bracts surrounding the female flowers (Figure 4).

Hemp produces a single-seeded fruit known as an achene. The hemp seed is oval-round, slightly flattened on two sides, with a blunt edge and a slightly pointed end opposite the scar, featuring a smooth surface with a characteristic net-like pattern (Figure 5). The seed's germination ability decreases over time, and hemp seeds contain no psychoactive substances.[10] Despite this, hemp seeds are available for purchase in illegal markets, and many websites offer them for sale. Popular brands include Royal Queen Seeds, Sensi Seeds: Cannabis Seeds Bank, and Green House Seed Company, among others. Retailers offer four main seed types: feminized, autoflowering, CBD, and F1 hybrid seeds. Feminized seeds guarantee the development of female plants, which are also photoperiodic. The goal in breeding autoflowering seeds was to produce plants that begin flowering independently of the light cycle. CBD seeds produce plants with a high concentration of cannabidiol (CBD). F1 hybrid seeds are created by crossing two pure genetic lines, ensuring that plants grown from these seeds consistently produce stable, uniform yields.[11]

Each seed type has various strains, differing mainly in active ingredient content, flavour, and intensity of effect. The morphological characteristics of hemp seeds do not indicate whether the resulting plant will have a high or low THC content.

In hemp plant remnants submitted for examination, stem, leaf, and fruit fragments, as well as stigmas, are most frequently found (Figure 6). Among the morphological traits required for species identification, cystolith hairs and glandular hairs on the surface of the remnants are most commonly available. In many cases, amber-coloured resin droplets can be observed on either seed coat fragments or pieces of bracts. When examining hemp remnants, an analytical test is also necessary for thorough characterization.

[10] Bócsa, I. (2004): Ibid. Chapter 4.6
[11] Source: https://www.royalqueenseeds.com

Figures 4 and 5
Female inflorescence of the cannabis plant with glandular trichomes (4) and seeds (5). Source: HIFS

Figure 6
Cannabis plant remnants. Source: HIFS

Peyote cactus and Peruvian torch cactus

The peyote cactus (*Lophophora williamsii* (Lem. Ex Salm-Dyck) J. M. Coult) belongs to the family Cactaceae. Commonly referred to as peyotl, bad seed, ciguri, or mescaline cactus, it has several synonyms, such as *Lophophora fricii* Habermann and *Lophophora williamsii var. lewinii* (Hennings) Coult. Although sold as a decorative plant in nurseries and online, it

is native to desert areas from Texas to Central Mexico. It is a slow-growing cactus, although horticultural techniques can accelerate its growth. Germination can take weeks, and it can be planted year-round, though it cannot tolerate frost. Peyote holds significant cultural importance in Central American indigenous rituals due to its psychedelic effects.

Morphologically, the peyote cactus is a small, flattened, spherical plant with a fleshy body and areoles (spine cushions). Its colour is bluish-gray, and it has a taproot. A key feature is the ribs along the body, whose number changes with age (5-8-10-13). Along these ribs, dirty white tufts of hair (trichomes) can be observed (Figure 7). The cactus produces light pink flowers from its center and soft, red fruit containing few seeds. [12,] Peyote seeds are black, broad, triangular, and slightly rough (Figure 8).

The peyote cactus contains over fifty alkaloids, with mescaline — a phenylethylamine derivative — being the primary psychoactive substance. The alkaloid is produced and stored in the plant's body but is absent in the seeds. The cactus is consumed fresh, dried, powdered, or as tea after soaking or boiling, regardless of the method, it has an intensely bitter taste. The effects of mescaline last 6-9 hours after absorption, and the plant retains its potency over time, regardless of storage conditions.[13] Due to overharvesting for traditional rituals, the wild peyote population has been declining, earning it a "Vulnerable" (VU) status on the IUCN Red List as of 2009.[14]

Apart from peyote, other mescaline-containing cacti belong to the Cactaceae family, such as the Peruvian torch cactus – *Cereus macrogonus* Salm-Dyck (syn.: *Trichocereus macrogonus* (Salm-Dyck) Riccob., *Trichocereus peruvianus* Britton & Rose, *Echinopsis peruviana* (Birtton & Rose)

[12] Rätsch, Ch. (2005): The Encylopedia of Psychoactive Plants, Etnopharmacology and Its Applications, Park Street Press, 821-857
Anderson, E. F. (1969): The biogeography, ecology, and teaxonomy pf Lophophora (Cactaceae), Brittonia,. 21:299-310

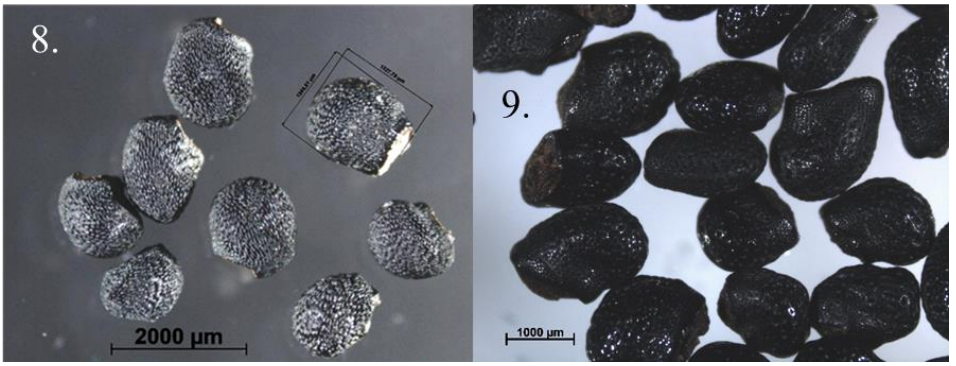
[13] Recommended Methods for Testing Peyote Cactus (Mescal Buttons) Mescaline and Psilocybe Mushrooms/Psilocybin – Manual for Use by National Narcotics Laboratories, United Nations, New York, 1989

[14] Source: https://www.iucnredlist.org/species/151962/121515326

H. Friedrich & G. D. Rowley). Based on the literature, the taxonomic classification and naming of the Peruvian torch cactus remain disputed to this day.[15] This cactus is native to Peru, Bolivia, and Ecuador, growing both in the wild and under cultivation. Also known as San Pedro, this is its local name.[16] According to archaeological descriptions, it was used in spiritual ceremonies due to its psychoactive effects, which are attributed to its mescaline content. Phenotypic differences exist between wild and cultivated varieties, as does mescaline distribution within the plant. The seeds of the Peruvian torch cactus are black, shiny, wide, and ovoid with a rough surface. They are flattened on both sides, and the dorsal side is convex with a ridge. The hilum (seed scar) is moderately slanted, with a diameter similar to the seed size. The seed coat is porous, with intermediate grooves giving it a rough texture, and under a microscope, it appears finely dotted[17] (Figure 9). Like peyote, the seeds do not contain mescaline. While the seeds retain their viability for a long time, the exact duration is not well documented.

Figure 7
Ribs of peyote cactus with dirty white tufts of hair. Source: HIFS

[15] Albesiano, S. – Kiesling, R. (2012): Identity and Neotypification of Cereus macrogonus, the type species of the genus Trichocereus (Cactaceae), Haseltonia 17: 24-34
[16] Rätsch, Ch. (2005): Ibid. 1276-1286
[17] Friedrich, H. – Glaetzle, W. (1983): Seed-morphology as an aid to classifying the genus Echinopsis Zucc., British Cactus and Succulent Society, Bradleya, 1:91-104. Source: https://doi.org/10.25223/brad.n1.1983.a9



Figures 8 and 9
Seeds of peyote cactus (8) and Peruvian torch cactus (9). Source: HIFS

Hawaiian baby woodrose

The Hawaiian baby woodrose (*Argyreia nervosa* (Burm. F.) Bojer) is a perennial climbing plant belonging to the family Convolvulaceae and the genus Argyreia. It is known by several common names, including elephant creeper and Hawaiian woodrose. The plant is native to India, but it has since become naturalized in various other regions, including Hawaii and parts of Africa. In addition to its wild populations, it is also cultivated as an ornamental plant. However, indoor-grown specimens generally do not produce flowers. Due to its decorative appearance, it is commonly used as a garden plant and is also applied in Ayurvedic medicine.

The plant exhibits rapid growth and can reach heights of 9 to 10 meters. Its stem becomes woody with age, and the leaves are arranged alternately. The leaves are bright green, measuring 15–25 cm in size, and are heart-shaped (Figure 10). A notable morphological feature of the leaves is their densely hairy, silvery undersides, while the upper surface is smooth. The size and shape of the leaves have inspired the common name "elephant creeper." The flowers are funnel-shaped and vary in colour from white to purple, with sepals that are also covered in hairs. The fruit is spherical and

berry-like, containing 1–4 seeds. The seeds are dark brown, with a characteristic quarter-circle shape. Their dorsal side is convex, while the ventral side is flat, meeting in a rounded edge. Both the apex and base of the seed are blunt, and the hilum, located at the base, is circular and lacks a surrounding ridge (Figure 11). The plant primarily reproduces by seeds, and their dispersal is facilitated by frugivorous birds and other animals.[18]

The Hawaiian Baby Woodrose contains lysergic acid amide (LSA), a psychoactive compound present in the seeds and the roots. LSA is chemically related to lysergic acid diethylamide (LSD), and is sometimes referred to as "natural LSD".[19] It has strong hallucinogenic properties, and in certain cultural contexts, such as Hawaiian traditions, the seeds are used in religious ceremonies. The seeds can be consumed whole, crushed, or mixed with hot water prior to ingestion. The effects of the compound typically last for 6–8 hours, although they may persist for longer. The psychoactive effects of Argyreia nervosa resemble those of the Ipomoea genus, particularly in species that also contain similar compounds.[20]

Figures 10 and 11
Leaves (10) and seeds (11) of Hawaiian baby woodrose. Source: Internet, powo.science.kew.org, HIFS

[18] Rätsch, Ch. (2005): Ibid. 137-145
[19] Paulke, A. – Kremer, Ch. – Wunder, C. – Wurglics, M. – Schubert-Zsilavecz, M. – Toennes, S. W. (2015): Studies on the alkaloid composition of the Hawaiian Baby Woodrose *Argyreia nervosa*, Forensic Science International, 249:281-293
[20] Rätsch, Ch. (2005): Ibid.

Psilocybe mushrooms

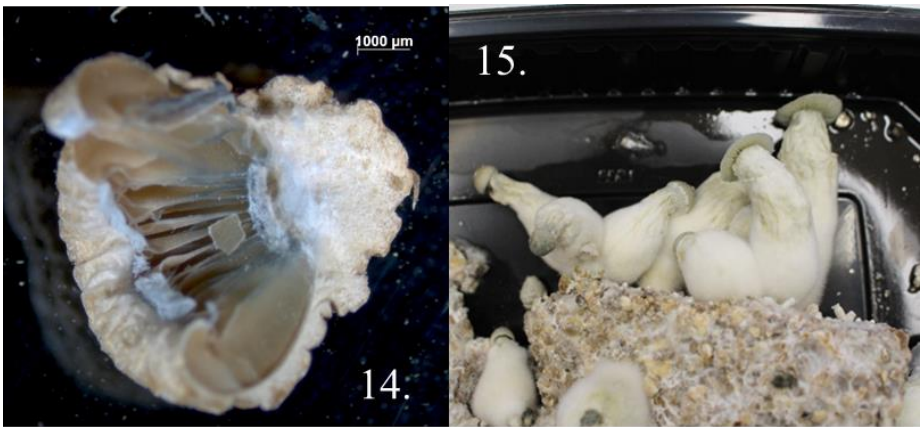
Psilocybe mushrooms (*Psilocybe spp.*) are Basidiomycete, cap-bearing fungi belonging to the family Strophariaceae and the genus Psilocybe. This cosmopolitan genus is found worldwide, predominantly in temperate regions. The genus comprises over 140 distinct species, but only about half of these contain psychoactive compounds. The use of psychedelic mushrooms in various ceremonies dates back thousands of years, with evidence showing their use by the inhabitants of the Aztec Empire. In the traditional practices of Mexican indigenous peoples, psychoactive species of Psilocybe, particularly *P. mexicana*, are still employed today. The most commonly encountered species in cases of drug-related abuse include *P. semilanceata*, *P. cubensis*, *P. mexicana*, and their hybrids.[21]

At the HIFS, samples of these fungi arrive in various forms for analysis: dried or fresh cap-bearing mushrooms (Figure 12), mushroom grow kits with substrates secondarily colonized by fungal mycelium, spore prints, spore suspensions, and sclerotia (Figure 13). The identification of these mushrooms requires extensive mycological expertise.

Due to the high species diversity within the genus, the morphology of Psilocybe mushrooms can vary widely. Their stipe can be whitish, yellowish-pink, or yellow, often with a bluish discolouration near the base, and may be hollow. Cap sizes range from 20 to 60 mm in diameter. The shape of the cap also varies, and may be conical, bell-shaped, shell-like, or expanding. The gills underneath the cap can range in colour from pale greyish-purple to dark gray or dark purplish-brown. A characteristic feature of psychoactive Psilocybe mushrooms is the appearance of a bluish discolouration at sites of injury (Figure 14).

[21] Recommended Methods for Testing Peyote Cactus, Ibid.
Rätsch, Ch. (2005): Ibid. 1652-1667
Guzmán, G. – Allen, J. W. – Gratz, J. (1998): A worldwide geogtaphical distribution of the neurotropic fungi, an analysis and discussion, Ann. Mus. civ. Rovereto, Sez.: Arch., St., Sc. nat., Vol. 14, 189-280, 2000

Figures 12 and 13
Dried specimens of Psilocybe mushrooms (12) and sclerotia (13). Source: HIFS



Figures 14 and 15
Halved, bluing Psilocybe cap (14) and Psilocybe grown on nutrient medium (15). Source: HIFS

Based on the hyphae found in mushroom cultivation boxes containing substrate that is secondarily colonized by hyphae, the identification of the species in question is not possible. This is because the hyphae do not possess morphological characteristics that would allow for species determination. In the case of mushroom boxes, the best method is to cultivate the

inoculated species and observe the morphological characteristics of the fruiting bodies that develop (Figure 15).

The spores of some species of Psilocybe do not show significant differences but may vary in colour and size. The characteristic morphological features of the spores are: dark brown, dark purplish-brown, reddish-brown colour; oval shape; double-walled; with a single germ pore; smooth surface; and size of 9–14×6–10 μm. Species identification based on spore morphology poses a significant challenge because these characteristics are also found in many other non-Psilocybe species.

Some fungal species are capable of forming what is known as a sclerotium. The sclerotium is a persistent structure of the fungus, representing an asexual reproductive form. It serves to enable the organism to survive under unfavourable conditions and also plays a role in nutrient storage.[22] The sclerotium consists of an outer, hard, melanized hyphal compaction (cortex) and an inner, thinner-walled, non-melanized hyphal network (medulla). Certain species of Psilocybe are capable of producing sclerotia (e.g., *P. mexicana*, *P. tampanensis*, *P. galindoi*). The Psilocybe sclerotium, like truffles, is an underground, dark brown, irregularly shaped substrate. The similarity in appearance is the reason for the name given by vendors and users, suggesting a resemblance to truffles; however, the two are not the same species. In commercial trade, the Psilocybe sclerotium is mostly marketed under the names "magic truffle" or "Philosopher's stone." The sclerotium, like the fruiting bodies, also contains psychoactive substances, but in lower amounts compared to the traditional fruiting bodies with cap and stipe.[23]

Among the psychotropic substances, some species of Psilocybe contain the active compounds psilocybin and psilocin.[24] According to literature, in

[22] Jakucs, E. (2003): A mikológia alapjai [The basics of mycology], ELTE Eötvös Kiadó, 30, 153, 165

[23] Pellegrini, M. – Rotolo, M. C. – Marchei, E. – Pacifici, R. – Saggio, F. – Pichini, S. (2012): Magic truffles or Philosopher's stones: a legal way to sell psilocybin?, Drug Testing and Analysis, 5(3):182-185

[24] Recommended Methods for Testing Peyote Cactus, Ibid.
Rätsch, Ch. (2005): Ibid. 1652-1667

addition to these compounds, some Psilocybe species – such as *P. semilanceata* – also contain psychoactive phenylethylamine (PEA).[25,]

Summary

The diversity of botanical mandates at the Laboratory of Forensic Geology and Botany, established in 2013 at the Department of Physics and Chemistry of the HIFS, has led to the continuous expansion of forensic botanical expertise. For the identification of various psychoactive plants and hallucinogenic mushrooms, it is necessary to review and develop existing methods and to create new procedures. Based on the experiences accumulated over the years since the Laboratory's establishment, the limitations beyond which progress is not possible have been clarified, while new, forward-looking solutions have also emerged.

[25] Presence of Phenethylamine in Hallucinogenic Psilocybe Mushrooms: Possible Role in Adverse reactions Journal of Analytical Toxicology, Vol. 22, January/February 1998. 78/2022. (XII. 28.) BM rendelet az ellenőrzött anyagokról, [78/2022.(XII. 28.) BM Decree on Controlled Substances] Annex 3